PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Looking Ahead

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FUTURE BALANCE OF ENERGY RESOURCES

Looking ahead

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I have the challenging task of summing up in a notional twenty minutes this fascinating two day Discussion Meeting.

First I will say something about the trends which have emerged from the papers and discussion. We began with the Secretary of State, who gave us a thoughtful paper showing a full recognition of the realities which constrain any power and energy policy. He told us that 'all energy predictions are wrong because of the great difficulty in predicting the demands and supplies'. He instanced this by saying that no one foresaw the North Sea development or the rapid progress with the breeder reactor, and went on to remind us that the balance between fuel sources may alter radically. So, from a policy-making angle we must have a flexible programme. He stressed the need to re-vitalize the coal industry, but warned us that new collieries take many years to bring in to production – as for instance, the 8–10 years for full production from the new Selby colliery.

Turning to the problems of the nuclear power programme he suggested that we would be moving to a situation where development was more international than hitherto. Having begun with several nuclear consortia, we now had a single national design and construction firm with the resources needed for operating on a world scale.

After the Secretary of State's paper, Sir Alan Hodgkin, P.R.S., asked about pooling information between countries. Mr Peter Walker said that he had plans for going ahead with joint research projects. Professor Kurti asked about improving insulation in buildings as a means of saving energy. The Secretary of State agreed that this was very worth while but suggested that, like so many other things, it is not possible to introduce an immediate step function change. There simply was not the industrial capacity to make large-scale improvements in thermal insulation in a short time.

Mr Darmstadter gave us an interesting review of the world energy requirements. A consistent package of policies was needed if a stable energy situation was to be achieved, but he expected the U.S. to weather the crisis. I thought at the time that perhaps he was being a little optimistic, and some later speakers felt the same. He also drew attention to shale and reminded us that this was the third time that the shale-oil proposition has come up, but it has always been overtaken by new discoveries of oil or gas reserves. He drew attention to the difficult environmental problems posed by shale oil.

I was interested that neither Mr Darmstadter nor indeed any other speaker in the whole of this meeting mentioned the possibility of saving oil by altering our ideas on transport. Dr McPhail of Canada has just given me a paper where he says that in the case of Canada – and I imagine the situation is very similar in the United States – a very large percentage of oil is used in private automobiles – about 78% for cars, 6% for aircraft, 3% for trains and 3% for inter-city and urban buses. A doctor friend of mine in Chicago has a Cadillac car with an 11 litre engine which

never runs at more than a small fraction of its potential power output. He has told me that i fuel consumption is less than 10 miles per gallon (~ 4 km/l). My own car is large b European standards, having a 3.5 litre engine which develops a maximum of 135 kW. Th will propel the car, whose mass is 1.5 tonnes, at nearly 200 km/h – well over 100 miles/h, ar far beyond any road speed limit. So I would suggest to our friends from North America th they should move to the greater use of more economical engines as an immediate means saving a substantial amount of oil. This is one change which could be implemented relative quickly to reduce the consumption of high-grade fuels.

Next we went on to an entertaining paper by Mr Ion, who gave us much information, presente in a lively way. In the discussion Professor Kurti and Sir Kingsley Dunham brought us bac to the question of units, and here we ought to clear things up before we go any farther. Th Royal Society has published a very useful booklet called 'Quantities, units and symbols'. M own organization has published British Standard 3763 on 'The international system of units These two documents are entirely in agreement and they draw attention to the fact that th unit of energy is the joule. Many speakers referred to the U.S. petroleum barrel. This contai 42 U.S. gallons or 35 Imperial gallons. Taking the energy value for paraffin, one barrel woul deliver some 5760 MJ of heat. Sir Kingsley Dunham also mentioned the unit Q, which I fir heard referred to by Dr Huomi Bhaba at the World Nuclear Energy Conference in Geneva i 1955. This unit is 10^{18} erg or 10^5 MJ. The Royal Society Secretariat have assured me that whe the proceedings of this meeting are recorded in *Philosophical Transactions*, the SI equivalent wi be given for all non-SI units, so comparisons will be much easier than with the variety units used by speakers.

Coming to coal, Mr Armstrong reminded us that this fuel is surprisingly consistent in qualit irrespective of its age or where it comes from. After taking us round the resources available i different parts of the world, he summarized the problem by saying that the geology and explor tion can be dealt with fairly easily, but the problem is to get the coal out. In the case of oil might cost £300M to explore a new off-shore field, but for the exploration of a new coal fiel the cost might be only £2M. He discussed new methods of mining which can operate in a 1:3 1:4 gradient, and ended by saying that basically there is no world shortage of coal but th reserves are badly distributed.

In the discussion Professor Thring made an interesting comment about his Telecheric robo He said that only 1% of the money which had been put into nuclear-energy research an development would have sufficed for the development of robots for the coal-mines. These robo would be able to win the coal from thin seams, vertical seams or seams far underneath the se He urged that imagination was needed to find reliable solutions for the mechanical engineerin problems involved. Several experts from the fuel side thought it was nothing like as simple that: it was a question of getting down to proper engineering design, ensuring that th equipment was completely fool-proof and had large margins for safety. I must agree with th view: any equipment of this kind must be designed for the overloads to which it will soon or later be subjected in service.

Moving on to oil, we had a stimulating presentation by Sir Eric Drake. His message w summed up in the last of his illustrations, which gave a projection of the main sources of energ to the year 1985. He reminded us that oil scarcity is a real possibility after 1978, and that fossi fuel resources are being used at a rate which will exhaust them in perhaps 100 years, which very short in geological time.

During the discussion we had a debate between Mr Ion and Mr Darmstadter on the energy forecast for the United States. Mr Shaw suggested that if you spent enough money looking, you are sure to find. Sir Eric replied that the dilemma is that you may find it, but you are not sure you can keep it: even if you spent millions of pounds in exploration the oil may be expropriated.

On gas, Mr Coppack gave us an account of the known reserves, which fall out roughly at one-third in U.S.S.R., one-sixth in North America, another sixth in the Middle East, and the rest elsewhere. He expected that most new discoveries would be made in the Soviet Union. For natural gas there are great possibilities, for example in the Celtic sea, and we may see gas piped to Europe from the Middle East. He also considered the possibility of methanol as a cheaper means of conveying a gas-based fuel over long distances because tankers are less expensive than the insulated ships needed for taking liquefied natural gas. He then suggested that airships may be used for gas transport, and finally he gave us another slide showing his prediction for gas production in the United States, which showed the expected decline from 1973.

Turning to hydro electricity, Mr Vernon said that 65% of the hydro resources were already used in the developed countries but only 10% in planned economies and a modest 3% in developing countries. This defines the scope for development, and he reminded us that, of the developed countries, Canada had the largest potential for further hydro schemes. Pump storage, with its very useful characteristic of being able to take a sudden peak load almost instantaneously, can be installed without spoiling the environment, as he showed in one of his illustrations. Tidal energy was almost a non-starter because of the very large capital investment costs. Until interest rates fell to 3 or 4% p.a. he foresaw little future for it.

Dr Bowie told us about natural sources of nuclear fuels, beginning with granite which contains about $4/10^6$ of uranium. In the discussion Mr Leslie made the point that the cost of ores is only 5% of the cost of a reactor, and claimed that a breeder reactor will use uranium something like 30 times more efficiently than a thermal reactor.

Professor Leardini showed us the interesting development of geothermal power in Italy and elsewhere. I will remember for a long time his picture of a 'blow-out' with steam gushing out over the Italian countryside. He showed us maps indicating where further geothermal sites might be found all over the world, but emphasized that their total contribution to world energy requirements would only be a modest one.

On our second day we considered energy conversion technology, beginning with Mr Grainger's paper on coal. He reminded us that there is plenty of coal in the ground, that coal is very versatile and that the reserves are sensitive to price. In other words, as the price rises it pays to work the more difficult seams. He then went on to talk about the very important new development of fluidized bed combustion combined with a pressurized 'Coalplex' or coal refinery. For power generation he mentioned the steam/gas-turbine cycle, which is a promising development for improving thermal efficiency, and is readily applicable to coal burning. He again emphasized the need for coordination on a national scale in research and development work spreading into the international field. In the discussion Sir Kenneth Hutchinson spoke about the work of the late Dr F. J. Dent, F.R.S., on the synthesis of methane, the slagging gasifier and other developments which still have a great deal to contribute to the energy situation in many countries.

Speaking about non-conventional hydrocarbons, Mr E. B. Walker reminded us of the

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enormous world appetite for energy, which meant we will need *all* forms of energy. He suggested that the situation was a continuum and I entirely agree. There was no major synthetic-fuel production going on at the moment but the possibility was attractive for the 1980s. He told us about the tar-sands and U.S. oil shales, and then went on to talk about developments based on coal conversion.

Mr Rooke told us about future trends in gas production and transmission, reminding us of the advantages of gas and that the demand far exceeded the supply. It is a premium fuel and burns to carbon dioxide and water vapour. He talked about pipeline techniques and I was patricularly interested to hear his mention of the new composite wound pipe, with which I had something to do in the early days with its inventor Mr Campbell Secord. This is a development which will have a role to play particularly in off-shore oil pipelines, for which its qualities make it specially suitable.

Mr Clark talked about energy conversion to electricity and gave us an insight into many aspects of the C.E.G.B.'s work. He reminded us that in its earlier years, nuclear power had to face falling real prices of fossil fuels, but I am sure all of us are very glad that the programme was allowed to continue. In the 1980 decade he predicted that new plant ordered would probably be roughly 75% nuclear and only 25% fossil-fuel fired. Finally, he made some interesting comments on transmission, showing us maps of the 400 kV 'supergrid' and said that this installation would see us into the 1980s. In the discussion we began by considering what happens to the waste heat from our power stations up and down the country. Mr Clark had to admit that most of it goes up the cooling towers. He did tell us about an interesting development of oysters growing at Stanswood Bay near Fawley Power Station, but this is a very small usage of waste heat. Several people were rather worried about the wastage and suggested we ought to do more to use the large amount of heat that is thrown away from any power station.

Dr Broom gave a paper on actual operating experiences in the nuclear power stations in this country, and I found this a most interesting account. He reminded us that the first nuclear chain reaction was only a little over 30 years ago, and showed us some of the problems of long-term effects on structures in a reactor and the expedients which have been developed for dealing with them.

We then had Sir John Hill telling us of the plans for further nuclear developments in this country. He reminded us that the industry began with five consortia and that the industrial structure was wrong. There is now a single company for construction and a single company for fuel processing. He looked to the fast reactor consuming 70% of its uranium, and reminded us that this makes the use of dilute ores practical politics. His remarks about dealing with fission products were reassuring on environmental grounds. He claimed that if fission products were sealed into glass with a stainless-steel casing round it, a single pond the size of a small field would look after our total storage requirements to the year 2000. Many people have been over-anxious about that important question.

There followed an interesting discussion on the question of terrorist attacks on nuclear stations, which showed some difficult problems and brought us into fundamental questions of our present social organization on which I will not dwell now.

Let me end by saying a few words about my view of the major changes which are to be expected. First, there can be no doubt that liquid and gaseous fossil fuels will become more expensive. Secondly, it is clear that coal is likely to stage at least a partial comeback, and it will probably be used for the synthesis of natural gas and oils as well as its traditional use in power

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stations. Thirdly, we can expect a steady growth of nuclear power with more economical systems.

These are likely to be our major energy sources in the 1980s, but there is likely to be progress in the use of solar energy, first directly, but I suspect also via biological processes. I am thinking here of two main routes – what has been called sea-farming, and the use of vegetation in fermentation processes. Fermentation occurs naturally in the production of marsh gas (methane) from vegetation in the bottoms of ponds and lakes, but it is now used on a large scale for sewage treatment. Here, a favourable energy balance is obtained because the activated sludge will produce enough methane to run the prime movers for the sewage works and leave some surplus for sale as a fuel. Another possibility is the production of the so-called 'wood alcohol' from cellulose waste.

Next we have got to think about conserving waste heat from all our power stations. I have great sympathy with our friends from the Generating Board, but I am sure that as fuel costs rise we will have to do more with the vast amounts of low-grade heat which at present are thrown away. We will also see the development of a variety of total-energy schemes. Perhaps this is a new subject to some people. In its simplest form you have a prime mover which produces the electric power needed. You then use the waste heat in winter for heating a building or a complex of buildings. In summer you can have a large absorption refrigerator and use the waste heat for air-conditioning and cooling. An increasing number of installations of that sort are being commissioned in the States, usually fairly small ones, but they deal with large shopping patios and blocks of flats giving a very high total-heat usage. The best case I know of is one in a linoleum factory where 91% of the heat in the fuel is used, thanks to the fact that large quantities of warm water are needed in the process.

I shall end with a prescription for a needed development in energy transmission which would greatly benefit the environment. This is for an underground transmission system for high-voltage electricity. With such a transmission the environment would be no more disturbed than it is by oil and gas pipelines. Whether we shall end up with superconductors or improved insulation with conventional conductors will emerge from research now in progress.

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